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Coal Recovery From Underground Bituminous Coal Mines in the United States, by Mining Method

UNITED STATES DEPARTMENT OF THE INTERIOR

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United States. Bureau of Mines.

Information Circular 8785

Coal Recovery From Underground Bituminous Coal Mines in the United States, by Mining Method

By Robert G. Reese, Binod B. Dash, and Patrick A. Hamilton

March 3, 1849

UNITED STATES DEPARTMENT OF THE INTERIOR
Cecil D. Andrus, Secretary

BUREAU OF MINES
Roger A. Markle, Director

YB

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

TN295
.U4
IC-8785, 1978

This publication has been cataloged as follows:

Reese, Robert G

Coal recovery from underground bituminous coal mines in the United States, by mining method / by Robert G. Reese, Binod B. Dash, and Patrick A. Hamilton. [Washington] : U.S. Dept. of the Interior, Bureau of Mines, 1978.

30 p. : ill., diagrs. ; 27 cm. (Information circular - Bureau of Mines ; 8785)

Includes bibliographical references.

1. Coal mines and mining - United States. I. Dash, Binod B., joint author. II. Hamilton, Patrick A., joint author. III. United States. Bureau of Mines. IV. Title. V. Series: United States. Bureau of Mines. Information circular - Bureau of Mines ; 8785.

TN23.U71 no. 8785 622.06173

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Stock No. 024-004-01937-9

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COAL RECOVERY FROM UNDERGROUND BITUMINOUS COAL MINES IN THE UNITED STATES, BY MINING METHOD

by

Robert G. Reese,[1] Binod B. Dash,[2] and Patrick A. Hamilton[3]

ABSTRACT

During fiscal year 1977 the Bureau of Mines conducted a study to estimate current recoveries obtained by different types of mechanized mining systems in underground coal mines. The study also attempted to define the effects on recovery of different coalbed and mine characteristics.

For this study, a number of deep mines were chosen from each major bituminous coal-producing State, and a procedure was developed for estimating the recovery obtained by each mining system used in these mines. This report gives a detailed account of this methodology and presents groupings of these estimates of recovery based on readily obtainable mine and coalbed characteristics such as mining method used, annual production, market served, and coalbed thickness. Using a statistical test and these groupings, relationships were developed from which conclusions could be drawn.

Other factors that may adversely affect recovery were identified by mine personnel but were not examined because of project constraints. A distribution showing the citation frequency of these factors is also included in this report.

INTRODUCTION

The increasing severity of energy shortages over the last several years demands that recovery of our fossil fuels should be as high as technologically possible. As part of its operations, the Bureau of Mines program for advancing coal mining technology sought development of new technology to improve the recovery of coal in the United States. Through this program, a need was recognized for an estimate of coal recovery obtained with current mining methods and technology. Such an estimate, combined with knowledge of factors that affect recovery and with information on coalbed characteristics, would define areas requiring research to improve current technology. Consequently, recovery percentages obtained by the mining industry might be increased.

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This study deals with the recovery being obtained in underground bituminous coal mines. It is related to an earlier Bureau of Mines study on this subject area,[4] and is complementary to a Bureau study done on the recovery obtained in surface mines.[5]

In the present study, six major types of mechanized mining systems were evaluated to determine their relative rates of recovery: (1) Continuous mining with full pillar extraction, (2) continuous mining with partial pillar extraction, (3) conventional mining with full pillar extraction, (4) conventional mining with partial pillar extraction, (5) longwall mining, and (6) shortwall mining. For each method, mines were identified and data gathered on various mine and coalbed characteristics that may affect coal recovery. Recovery percentages were calculated for these mines and related to these different characteristics.

ACKNOWLEDGMENTS

Successful completion of this study was due to the cooperation and assistance of many people within the Bureau of Mines and the coal mining industry. Special acknowledgments are due the various Bureau of Mines State Liaison Officers for their guidance and help in establishing contact with members of the mining industry in their States. Special acknowledgment is due the Kentucky Coal Association for its endorsement of the study and aid in establishing contact with personnel from several Kentucky mines. Grateful acknowledgment is made to Eric Norman, a student associate at the Pittsburgh Energy Data Field Office, and to many individuals at the Denver Energy Data Field Office for their diligent work in planimetering the mine maps to determine a recovery estimate. Finally, the authors wish to acknowledge and thank the personnel from the different coal companies for their information, help, and cooperation.

STUDY METHODOLOGY

Sample Selection

As a planning guide, a sample size of 100 mines was chosen for this study. This number was chosen to give adequate coverage to the six primary types of mining systems being employed in the major bituminous-coal-producing regions of the United States while considering constraints of time, manpower availability, and funding. It was agreed later that the 100 mines would represent the minimum number of mines used in this study. Whenever possible, data would be gathered from additional mines. As a result, a total of 103 mines from 13 States as shown in table 1 constituted the final sample. These mines had a 1976 production of 56,521,000 tons, which represents 19.1 percent of the total U.S. underground bituminous coal production for 1976. The 103 mines represented approximately 4 percent of the underground bituminous coal mines in operation in 1976.

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[4] Lowrie, R. L. Recovery Percentage of Bituminous Coal Deposits in the United States. BuMines RI 7109, 1968, 19 pp.

[5] Secor, E. S., G. M. Larwood, A. B. Gupta, and A. S. Lees. Coal Recovery From Bituminous Coal Surface Mines in the Eastern United States, A Survey. BuMines IC 8738, 1977, 14 pp.

TABLE 1. - Distribution of sample mines by State, and distribution of sample sections within these mines by State and mining method

State	Mine sections by mining method							
	Continuous with full pillar extraction	Continuous with partial pillar extraction	Conventional with full pillar extraction	Conventional with partial pillar extraction	Longwall	Shortwall	Total sections	Total mines
Alabama.........	1	0	0	2	0	0	3	2
Colorado........	1	8	0	0	1	0	10	9
Illinois........	2	6	0	6	1	0	15	4
Kentucky........	7	10	0	7	2	2	28	13
New Mexico......	1	0	0	0	1	0	2	1
Ohio............	0	9	0	2	0	0	11	5
Pennsylvania....	30	3	0	0	17	4	54	18
Tennessee.......	4	0	3	0	0	0	7	3
Utah............	2	10	0	2	2	0	16	15
Virginia........	4	0	0	0	4	0	8	3
West Virginia...	26	14	0	17	17	13	87	29
Wyoming.........	0	1	0	0	0	0	1	1
Total......	78	61	3	36	45	19	242	103

For the purposes of this study, sample distribution was based on type of mechanical mining system used. These systems include (1) continuous mining with full pillar extraction, (2) continuous mining with partial pillar extraction, (3) conventional mining with full pillar extraction, (4) conventional mining with partial pillar extraction, (5) longwall mining, and (6) shortwall mining. Because source material used to make the sample distribution prevented mine identification based on the amount of pillar removal attempted, this distinction within continuous and conventional mining systems was disregarded when making the initial sample distribution. It was felt that through the process of random selection, a representative distribution would result, which reflected the use of partial and full pillar extraction in the United States.

A proportional distribution based on the use of different mining systems was eliminated because so few mines presently use longwall and shortwall methods compared with the number using continuous and conventional room-and-pillar methods. As a result, in a proportional distribution longwall and shortwall mining systems would not be adequately represented. Therefore, it was decided that the proposed distribution should keep the representation of the four systems as equal as possible in an attempt to insure adequate representation of each type. In the case of mines using more than one type of mining method, it was decided to obtain information on each type used. This increased the section inequality shown in table 1, but it allows comparisons between different types of mining methods with as many factors controlled as possible.

The sample was distributed geographically. The distribution was made among the 13 major bituminous-coal-producing States. Because of the overwhelming number of underground mines in States east of the Mississippi River, a proportional or stratified distribution was ruled out in order to insure a meaningful representation of western mines. The distribution of the mine sample was made so that additional weight would be given the mining industry west of the Mississippi River, because the rapid recent development of these coalfields might reflect more clearly the effects on recovery of new technology and recent Government laws and policies. Using the minimum sample size as a base, along with the number of identified western mines, it was decided that a maximum of 32 mines would be from the western coalfields with a minimum of 68 mines coming from the eastern areas. Within each of these regions, distribution among the individual States was to be proportional to the number of mines in that State subject to the following guidelines: (1) If possible, at least two mines should be included from each State; (2) if a mining method could be identified as used within a State, a mine using that method should be included if possible.

Fieldwork

Information was gathered during visits of Bureau personnel with members of the mining industry at each company's office. The people interviewed were those familiar with the chosen mine. During the visit mine personnel were asked to identify areas within the mine that they felt to be typical of conditions encountered during mining. Also during these visits, information was gathered about each company's mining procedure, taking into consideration the conditions encountered in the coalbed as well as opinions concerning the percentage of recovery obtained.

The following information was either gathered during the visit or assembled and sent to the Bureau later at the company's convenience. First, an interview guide was completed. This consists of general questions which attempt to identify characteristics and conditions encountered in mining the coalbed, effects of various factors on recovery, and criteria for determining the recovery being obtained by the mine. Second, portions of the mine map were obtained for those areas identified by mine personnel as typical of the mine. These maps either were 1 inch = 100 feet or 1 inch = 200 feet in scale or were enlarged to one of these scales at the Bureau. Finally, if pillar extraction was done within the typical areas, a copy of the roof control plan (pillar plan) used for this work was obtained.

Definitions of Terms and Concepts

The nature of this study and the criteria that only data from recently mined out areas should be used to determine recovery resulted in a need for definitions to define our concepts of typical areas, barriers and other unrecovered coal, and recovery. Also a need was recognized for a definition of what would be considered full pillar recovery and what would be partial pillar recovery. The corresponding definitions follow:

Section.--Areas identified as typical of the mine represented portions of former working areas and were defined as sections for the purposes of this study. These sections typically were mined by a group of men under a section foreman. In the case of continuous and conventional mining methods, sections were restricted to those workings that were mined utilizing only one type of equipment. For example, a section classified as continuous mining with full pillar extraction was developed and retreated by using a continuous miner and associated support equipment.

For the purpose of planimetering, a section was defined as a set of workings off the main entry system. The length and width of a section was determined by the location of the workings within the mine. Length and width were assumed to be represented by the extent of mining shown on the map unless the extent of the mine property, coal outcrop line, or barrier pillars were also indicated. In the case of barrier pillars between two sets of workings, or between the workings and main entry system, half their area was assigned to the workings defined as a section; the remainder was regarded as part of the other workings or main entries. In cases where the workings were proximate to the coalbed outcrop line or the limits of the mine property, the general trend of the section was determined. The boundaries defining the section in these directions were located and extended until the outcrop line or property

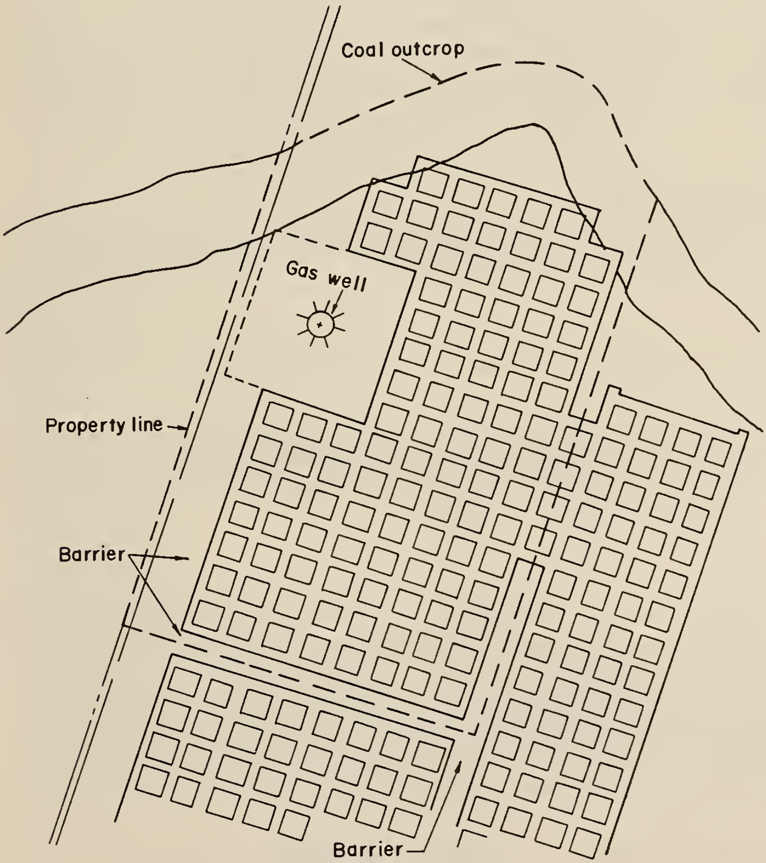

FIGURE 1. - Simulated map of section mined by either continuous or conventional mining equipment.

boundary was intersected. All the area between the workings, the extended boundaries, and the outcrop line or property limit was included in the area considered to be a section.

Graphical representations incorporating this definition of a section are presented in figures 1, 2, and 3. Due to the similar nature of continuous mining with full and partial pillar extraction and conventional mining with full and partial pillar extraction, these four mining systems have been combined into one graphical representation of the definition in figure 1.

Barrier.--The definition of a barrier as used in this study was the same as that used in the Bureau's Dictionary of Mining, Mineral, and Related Terms,[6] which defines a barrier as "Blocks of coal left between the workings of different mine owners and within those of a particular mine for safety and the reduction of operations costs. It helps to prevent disasters of inundation by water, of explosions, or fire involving an adjacent mine or another part of a mine and to prevent water running from one mine to another or from one section to another of the same mine." In addition, barrier, as used in this report, refers to relatively solid blocks of coal left to protect workings from squeezes in adjacent areas.

Coal Losses.--Coal losses as used in this report refers to any coal unmined and left in the section. Among the different types encountered were (1) barriers left to protect either the mine or adjacent areas within the mine, (2) top coal left to prevent deterioration of the roof strata,

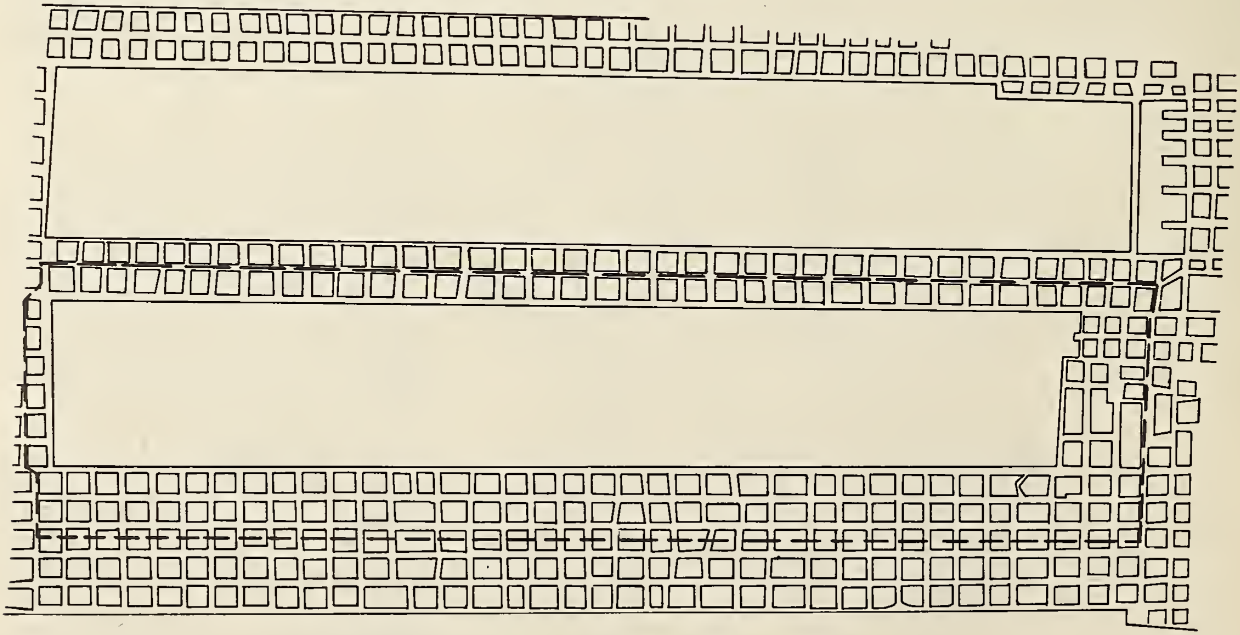

FIGURE 2. - Simulated map of a longwall section.

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[6] Thrush, Paul W. (comp.). A Dictionary of Mining, Mineral, and Related Terms. BuMines Special Publication, 1968, 1269 pp.

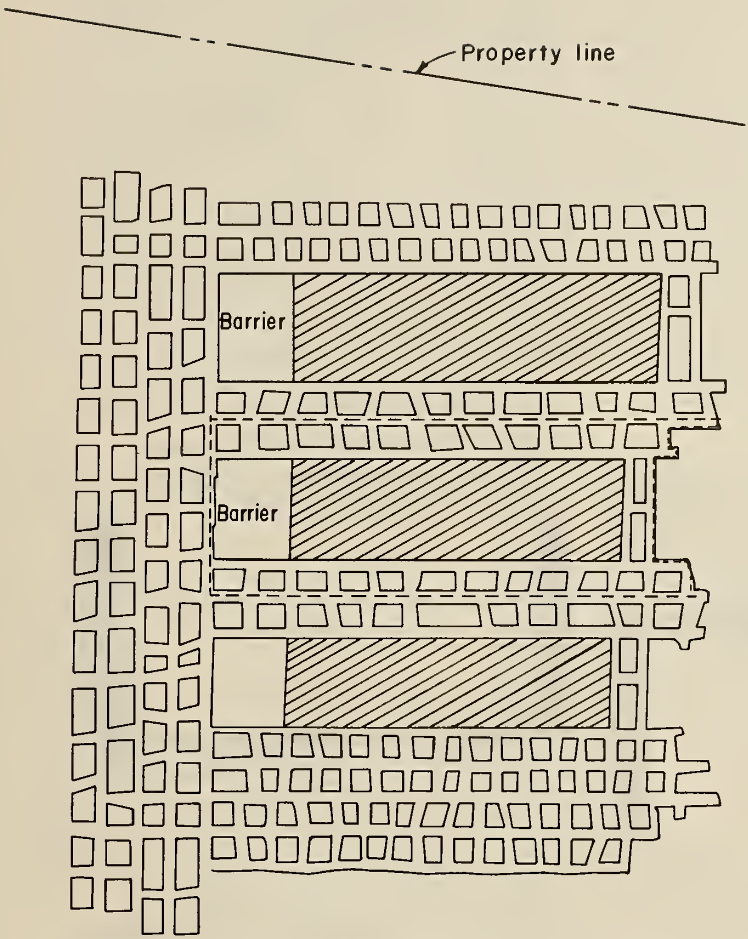


FIGURE 3. - Simulated map of a shortwall section.

(3) bottom coal left to preserve the floor, (4) identified areas of thin coal that were too low for the equipment currently used to mine effectively or economically, (5) barriers of coal left around oil and gas wells to prevent possible inflows of these materials into the mine, and (6) lenticular deposits of coal which vary in thickness and for which no methods were available for determining the vertical extent of the coal. Figure 4 shows a series of graphical simulations representing these various coal losses.

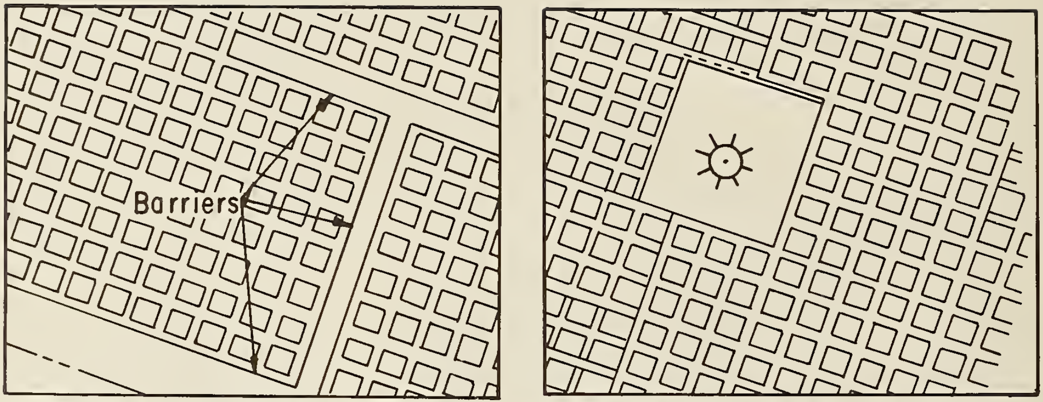
Recovery.--Recovery as used in this study was the proportion or percentage of the original inplace coal that was mined. Extraction losses such as spillage were disregarded. The equations used to calculate the recovery estimates follow:

For recovery calculations which include the areas classified as barriers within a section--

$$R = \frac{A\bar{T} - CT_c - P\bar{T}U}{A\bar{T}} (100) \qquad (1)$$

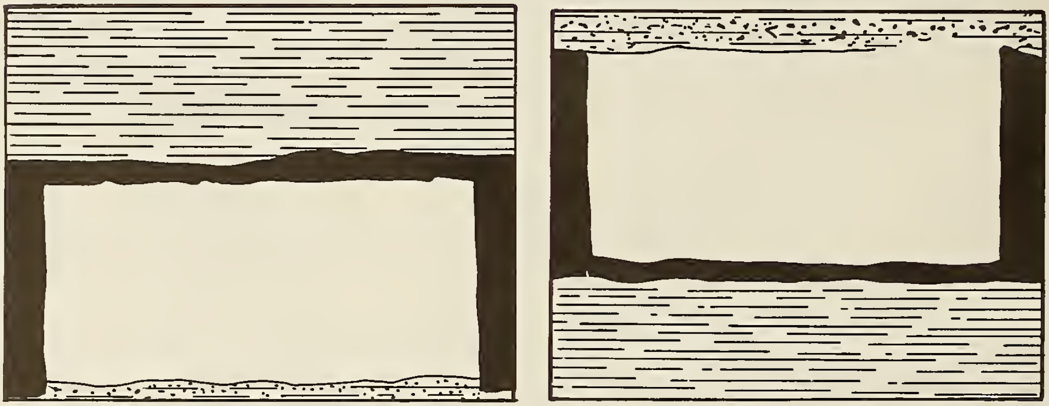
For recovery calculations concerned with the recovery percentage for only that area actually mined or available for mining--

$$R = \frac{A\bar{T} - CT_c - P\bar{T}U}{A\bar{T} - BT_b} (100) \qquad (2)$$



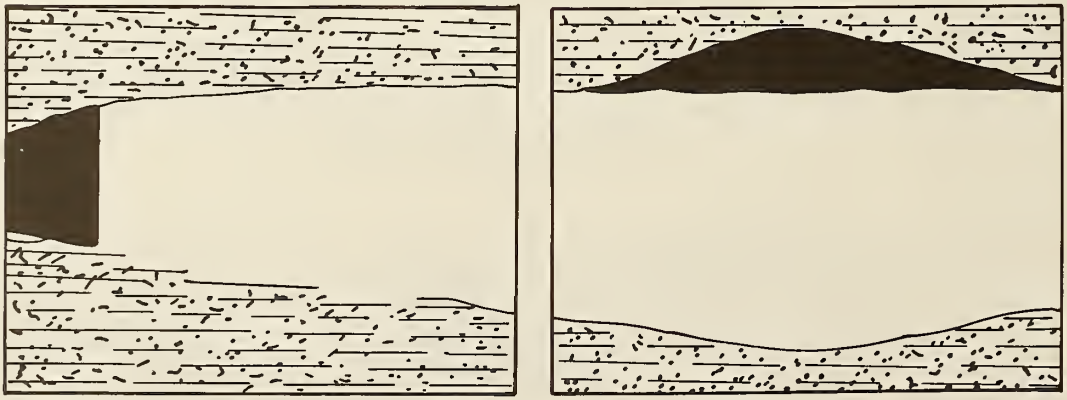
a. Plan view of barriers left to protect the mine or adjacent areas within the mine.

b. Plan view of barriers left around oil and gas wells to protect the mine from inundations of these materials.



c. Section view of top coal left to protect against deterioration of a weak roof.

d. Section view of bottom coal left to protect a weak floor from deterioration.



e. Section view of areas identified on the mine map as too thin for economical mining using the present equipment.

f. Section view of lenticular deposits for which the full thickness cannot always be taken.

FIGURE 4. - Graphical representation of coal losses considered when making recovery estimates.

where R = recovery percentage,

A = total area of the section,

C = the area of a particular coal loss,

$\overline{T}$ = the average thickness of the coalbed,

T_c = the average thickness of the coal loss,

T_b = the average thickness of the barriers,

B = the area of the barriers,

P = total area of the pillars,

and U = the proportion of the pillar not recovered as calculated from the pillar plan.

Partial Pillar Extraction.--Partial pillar extraction as used in this work refers to when no attempt was made to recover all the coal in an area but instead a portion was left in the form of pillars for preservation of surface topography or for economic considerations. An attempt was made to obtain the desired level of extraction when development or first mining work was done. Sometimes, however, the percentage of recovery was increased by slabbing the pillars, by splitting them, or by taking several lifts or cuts at various locations on the pillar. All four methods were encountered in the study and were classified as partial pillar extraction since no attempt was made to recover all of the available coal.

Full Pillar Extraction.--Full pillar extraction refers to the attempt to recover all coal available or allowed by law in a set of workings. This was done by developing a set of workings to its maximum during first mining and later attempting to rob or recover the coal remaining in the pillars, resulting in caving and lowering of the overlying strata after removal of the pillars.

Assumptions

The procedure used in this study represents a method of determining theoretical recovery in specific areas for any given mine. In this procedure two assumptions were made. The first assumption was that the mine map accurately represents the work done underground, and while area measurements calculated for workings shown on the map may be erroneous, these errors will cancel each other, because areas underrepresented in one portion of the section will be nullified by overrepresentation of other similar areas. Therefore, planimeter work done on a small area such as an individual pillar, while possibly being wrong, will result in an accurate estimate of the total pillar area when combined with the area of all the pillars.

The second assumption concerned the accuracy of the pillar plan. Because no underground work was done in this study, it was assumed that any pillar work done in a section was the same as that represented on the pillar plan. Therefore, by planimetering the pillar plan, an estimate could be made of the percentage of the pillar extracted. This could then be used in estimating the recovery of a section. In those mines using full pillar recovery it was assumed that while in some instances 100 percent or close to it of the pillar was recovered, overall the recovery was not this high. As a result, through discussions with mine personnel, the criterion was established that the maximum overall pillar recovery in a section would be approximately 85 percent. This was the figure used for those mines whose pillar plans call for pillar recovery greater than 85 percent, thereby limiting the values of U used in the recovery formulas from 1.00 to 0.15, depending on the amount of a pillar left unrecovered.

With these assumptions the analysis procedure was broken into four stages. First, an area to be designated as a section along with its definable barriers and coal losses was identified on the maps obtained from the company. Second, the identified sections were planimetered using either a graphic calculator or a manual planimeter to determine their areas. Third, recovery percentages were calculated using the formulas given above. This resulted in two estimates, one including the barriers as part of the total area, and one excluding the barriers as part of the total area. Finally, these results were classified in terms of the factors and coalbed characteristics identified as possibly affecting recovery.

Factors Affecting Recovery

The factors that might affect recovery were divided into unquantifiable factors and quantifiable factors. Unquantifiable factors, such as subsidence constraints and water problems, required more investigation at individual mines than was possible in this study. As a result, no attempt was made to develop relationships between these factors and the calculated recovery figures.

Quantifiable factors referred to those mine and coalbed characteristics, such as annual production, market served, location, and coalbed thickness, that were readily obtainable. It was with these factors that all statistical work in this study was done.

The calculated recovery figures were grouped according to the quantifiable factors of the mine from which they were obtained, and the type of mining system used in this section. From these groupings, the mean, standard deviation, range, and number of sections in the group were determined. Because it was believed that two or more quantifiable factors may act jointly to affect recovery, groupings were also made of the recovery figures based on different combinations of the quantifiable factors taken two at a time, and the mining system used. Again, the mean, standard deviation, range, and number of sections were determined for each of these groups. No division of data was made based on combinations of three or more quantifiable factors because the number of sections in any group would probably be very small, decreasing confidence in these results.

Once these groups were made and the relevant statistics calculated, a T test was used to check for significant differences between the groups and a composite population represented by grouping the recovery factors solely on the type of mining system used in the section. For example, within a table, the mean of each group using continuous mining with full pillar extraction was compared with the mean calculated for all sample sections using continuous mining with full pillar extraction.

The T statistic used for this comparison was calculated from the following relationship:

$$T_{(n-1)} = (\bar{x} - \mu_o)/(s/\sqrt{n})$$

where $T_{(n-1)}$ = T statistic with (n-1) degrees of freedom,

$\bar{x}$ = mean of a group,

μ_o = mean of all sections utilizing the same mining method used in the group,

s = standard deviation of a group,

and n = number of sections in the group.

The T statistic resulting from this calculation was used to test the following hypothesis: $\mu=\mu_o$ versus $\mu\neq\mu_o$, a two-tailed test. The significance level chosen for this test was 0.10. Using statistical tables for the T distribution, if the cacluated T statistic was larger than the value found in the table, or smaller than the negative of this value for the same number of degrees of freedom and a significance level of 0.10, then the hypothesis $\mu\neq\mu_o$ was accepted. If our calculated statistic was greater than the table's T value, this indicated that the sections which made up that group were probably chosen from a population of sections which had a higher mean value than the one calculated for all sample sections using the same mining method. The reverse situation occurs for calculated T values smaller than the negatives of the ones shown in the table. In these cases, the mean of the population from which the group was chosen was probably smaller than the one calculated for all sections. If the calculated T statistic was not larger than the table value or smaller than the negative of the table value, then the hypothesis $\mu=\mu_o$ was accepted. This implied that both figures could result from samples chosen from the same population.

ANALYSIS OF DATA

Recovery estimates including barriers in the mined area and excluding barriers in the mined area were calculated using the formulas developed previously. However, most of the statistical analysis of these estimates was done using the figures calculated excluding barriers from the mined area, because some maps did not indicate the full extent of the barriers, thus reducing the number of sections that could be included in the sample.

There appeared to be several advantages to using the recovery estimates without barriers: (1) Comparisons could be made of areas actually mined, removing the effect of surface physiography, (2) corrections could be made for the location of sections in different areas of the mine, and (3) the number of sections that could be included in the sample was increased. There is one major disadvantage to this method: recovery estimates made without inclusion of barrier areas were higher than those actually obtained. However, since all figures were higher, it was felt that the comparative relationships should remain the same.

The recovery estimates were grouped according to their quantifiable characteristics. These groupings were tabulated and placed into tables 2 through 9. Table 2 presents the recovery estimates calculated with barriers included, based on the type of mining method employed and State location. Tables 3 through 9 then present groupings of the recovery estimates excluding barriers, based on the type of mining method employed and different quantifiable factors. Table 10 presents those unquantifiable factors which mine company personnel indicated adversely affected recovery in the sample mines, along with the frequency with which these factors were cited. Table 11 presents cumulative estimates of recovery made by mine company personnel.

TABLE 2. - Group statistics using recovery figures with barrier areas included, by State and mining method

State and parameter	Mining method					
	Continuous		Conventional		Longwall	Shortwall
	Full pillar	Partial pillar	Full pillar	Partial pillar		
Alabama:						
Mean	NA	NA	NA	W	NA	NA
Standard deviation	NA	NA	NA	NA	NA	NA
Number of sections	NA	NA	NA	1	NA	NA
Range of sample	NA	NA	NA	NA	NA	NA
Colorado:						
Mean	NA	49.1	NA	NA	W	NA
Standard deviation	NA	13.2	NA	NA	NA	NA
Number of sections	NA	7	NA	NA	1	NA
Range of sample	NA	27.9-61.9	NA	NA	NA	NA
Illinois:						
Mean	65.1	49.9	NA	49.3	W	NA
Standard deviation	1.6	8.9	NA	9.6	NA	NA
Number of sections	2	6	NA	6	1	NA
Range of sample	63.9-66.2	38.1-61.1	NA	32.3-60.4	NA	NA
Kentucky:						
Mean	68.9	53.1	NA	51.9	74.6	[1]78.0
Standard deviation	7.6	9.8	NA	5.3	1.3	.4
Number of sections	7	10	NA	7	2	2
Range of sample	58.0-78.5	29.1-62.1	NA	47.0-60.3	73.7-75.5	77.7-78.3
New Mexico:						
Mean	W	NA	NA	NA	W	NA
Standard deviation	NA	NA	NA	NA	NA	NA
Number of sections	1	NA	NA	NA	1	NA
Range of sample	NA	NA	NA	NA	NA	NA
Ohio:						
Mean	NA	51.4	NA	53.3	NA	NA
Standard deviation	NA	6.1	NA	12.2	NA	NA
Number of sections	NA	5	NA	2	NA	NA
Range of sample	NA	45.9-61.7	NA	44.6-61.9	NA	NA
Pennsylvania:						
Mean	70.1	57.6	NA	NA	70.3	69.0
Standard deviation	11.3	8.6	NA	NA	10.8	7.7
Number of sections	26	3	NA	NA	14	4
Range of sample	46.3-84.6	52.5-67.5	NA	NA	43.6-79.5	57.5-73.9

See footnotes at end of table.

TABLE 2. - Group statistics using recovery figures with barrier areas included, by State and mining method--Continued

State and parameter	Mining method					
	Continuous		Conventional		Longwall	Shortwall
	Full pillar	Partial pillar	Full pillar	Partial pillar		
Tennessee:						
Mean	77.6	NA	62.3	NA	NA	NA
Standard deviation	9.7	NA	4.3	NA	NA	NA
Number of sections	3	NA	3	NA	NA	NA
Range of sample	67.4-86.6	NA	57.3-65.1	NA	NA	NA
Utah:						
Mean	51.5	54.1	NA	NA	NA	NA
Standard deviation	21.1	22.3	NA	NA	NA	NA
Number of sections	2	2	NA	NA	NA	NA
Range of sample	36.6-66.4	38.3-69.9	NA	NA	NA	NA
Virginia:						
Mean	61.5	NA	NA	NA	[1]76.0	NA
Standard deviation	7.7	NA	NA	NA	2.7	NA
Number of sections	3	NA	NA	NA	4	NA
Range of sample	52.6-66.2	NA	NA	NA	73.8-79.8	NA
West Virginia:						
Mean	72.5	49.7	NA	52.6	72.2	[2]61.0
Standard deviation	10.2	9.5	NA	9.6	4.9	6.7
Number of sections	25	14	NA	15	17	8
Range of sample	50.7-88.6	38.0-74.5	NA	38.1-74.8	64.8-83.5	49.4-69.2
Wyoming:						
Mean	NA	W	NA	NA	NA	NA
Standard deviation	NA	NA	NA	NA	NA	NA
Number of sections	NA	1	NA	NA	NA	NA
Range of sample	NA	NA	NA	NA	NA	NA
Total:						
Mean	70.2	51.0	62.3	51.6	72.4	65.7
Standard deviation	10.9	9.9	4.3	8.5	7.7	8.9
Number of sections	69	48	3	31	40	14
Range of sample	36.6-88.6	27.9-74.5	57.3-65.1	32.3-74.8	43.6-83.5	49.4-78.3

NA Not available.

W Withheld to avoid disclosing individual company data.

[1] Group mean is significantly higher than the mean for all sections using the indicated mining system.

[2] Group mean is significantly lower than the mean for all sections using the indicated mining system.

TABLE 3. - Group statistics using recovery figures excluding all barrier areas within a section, by State and mining method

State and parameter	Mining method					
	Continuous		Conventional		Longwall	Shortwall
	Full pillar	Partial pillar	Full pillar	Partial pillar		
Alabama:						
Mean	W	NA	NA	59.0	NA	NA
Standard deviation	NA	NA	NA	12.7	NA	NA
Number of sections	1	NA	NA	2	NA	NA
Range of sample	NA	NA	NA	50.0-67.9	NA	NA
Colorado:						
Mean	W	62.5	NA	NA	W	NA
Standard deviation	NA	11.3	NA	NA	NA	NA
Number of sections	1	8	NA	NA	1	NA
Range of sample	NA	43.5-75.0	NA	NA	NA	NA
Illinois:						
Mean	[1]72.6	64.2	NA	65.4	W	NA
Standard deviation	1.6	7.2	NA	10.7	NA	NA
Number of sections	2	6	NA	6	1	NA
Range of sample	71.4-73.7	53.5-74.9	NA	45.8-77.2	NA	NA
Kentucky:						
Mean	81.8	[2]71.9	NA	65.3	77.4	[2]81.6
Standard deviation	6.0	5.0	NA	7.8	1.3	.6
Number of sections	7	10	NA	7	2	2
Range of sample	70.7-87.5	66.4-81.3	NA	56.8-73.9	76.4-78.3	81.1-82.0
New Mexico:						
Mean	W	NA	NA	NA	W	NA
Standard deviation	NA	NA	NA	NA	NA	NA
Number of sections	1	NA	NA	NA	1	NA
Range of sample	NA	NA	NA	NA	NA	NA
Pennsylvania:						
Mean	[2]82.9	74.0	NA	NA	79.4	76.6
Standard deviation	5.7	14.3	NA	NA	4.5	7.3
Number of sections	30	3	NA	NA	17	4
Range of sample	70.6-91.7	59.2-87.7	NA	NA	66.9-85.9	65.7-81.0
Tennessee:						
Mean	82.9	NA	75.6	NA	NA	NA
Standard deviation	4.9	NA	2.3	NA	NA	NA
Number of sections	4	NA	3	NA	NA	NA
Range of sample	78.1-87.5	NA	73.0-77.6	NA	NA	NA

See footnotes at end of table.

TABLE 3. - Group statistics using recovery figures excluding all barrier areas within a section, by State and mining method--Continued

State and parameter	Mining method					
	Continuous		Conventional		Longwall	Shortwall
	Full pillar	Partial pillar	Full pillar	Partial pillar		
Utah:						
Mean	83.6	56.4	NA	[1]39.3	76.7	NA
Standard deviation	6.5	19.1	NA	1.3	3.0	NA
Number of sections	2	10	NA	2	2	NA
Range of sample	79.0-88.2	33.0-87.3	NA	38.4-40.2	74.6-78.8	NA
Virginia:						
Mean	[1]70.8	NA	NA	NA	78.4	NA
Standard deviation	3.0	NA	NA	NA	2.3	NA
Number of sections	4	NA	NA	NA	4	NA
Range of sample	66.5-73.4	NA	NA	NA	76.6-81.6	NA
West Virginia:						
Mean	79.4	66.9	NA	[2]70.9	76.5	[2]67.5
Standard deviation	8.8	13.0	NA	8.1	4.3	2.7
Number of sections	26	14	NA	17	17	13
Range of sample	61.3-91.9	48.1-86.4	NA	60.0-87.1	69.3-85.1	63.0-73.8
Wyoming:						
Mean	NA	W	NA	NA	NA	NA
Standard deviation	NA	NA	NA	NA	NA	NA
Number of sections	NA	1	NA	NA	NA	NA
Range of sample	NA	NA	NA	NA	NA	NA
Total:						
Mean	80.7	64.3	75.6	66.2	78.3	70.9
Standard deviation	7.2	12.9	2.3	10.8	4.8	6.5
Number of sections	78	61	3	36	45	19
Range of sample	61.3-91.9	33.0-87.7	73.0-77.6	38.4-87.1	66.9-85.9	63.0-82.0

NA Not available.

W Withheld to avoid disclosing individual company data.

[1] Group mean is significantly lower than the mean for all sections using the indicated mining system.

[2] Group mean is significantly higher than the mean for all sections using the indicated mining system.

TABLE 4. - Group statistics using recovery figures excluding all barrier areas within a section, by thickness category and mining method

Thickness category and parameter	Mining method					
	Continuous		Conventional		Longwall	Shortwall
	Full pillar	Partial pillar	Full pillar	Partial pillar		
<40 inches:						
Mean	76.0	[1]69.7	75.6	NA	NA	NA
Standard deviation	5.3	4.4	2.3	NA	NA	NA
Number of sections	2	4	3	NA	NA	NA
Range of sample	72.2-79.7	64.3-73.5	73.0-77.6	NA	NA	NA
40 to 59 inches:						
Mean	81.5	[1]70.0	NA	67.7	[1]79.7	76.3
Standard deviation	5.8	10.2	NA	7.9	3.5	9.2
Number of sections	32	25	NA	26	22	3
Range of sample	66.5-89.7	52.2-87.7	NA	45.8-80.6	74.0-85.9	65.7-82.0
60 to 79 inches:						
Mean	[1]82.8	59.9	NA	68.0	77.4	72.3
Standard deviation	5.8	13.0	NA	12.0	3.8	6.4
Number of sections	32	14	NA	8	16	9
Range of sample	70.6-91.9	42.8-87.3	NA	56.8-87.1	66.9-81.8	66.2-81.0
80 to 99 inches:						
Mean	[2]73.4	60.6	NA	38.4	75.8	[2]66.9
Standard deviation	9.3	14.2	NA	NA	8.3	2.5
Number of sections	8	10	NA	1	7	7
Range of sample	61.9-91.6	33.0-75.0	NA	NA	69.3-93.9	63.0-69.8
>99 inches:						
Mean	73.5	56.4	NA	NA	40.2	NA
Standard deviation	12.4	14.7	NA	NA	NA	NA
Number of sections	4	8	NA	NA	1	NA
Range of sample	61.3-88.2	36.8-81.3	NA	NA	NA	NA

NA Not available.

[1] Group mean is significantly higher than the mean for all sections using the indicated mining system.

[2] Group mean is significantly lower than the mean for all sections using the indicated mining system.

TABLE 5. - Group statistics using recovery figures excluding all barrier areas within a section, by the mine's 1976 level of production and mining method

Production in 1976 and parameter	Mining method					
	Continuous		Conventional		Longwall	Shortwall
	Full pillar	Partial pillar	Full pillar	Partial pillar		
<300,000 tpy:						
Mean	79.8	68.4	75.6	70.3	[1] 82.6	NA
Standard deviation	4.3	13.0	2.3	12.8	1.7	NA
Number of sections	7	20	3	12	4	NA
Range of sample	72.2-85.7	36.8-87.7	73.0-77.6	40.2-87.1	81.3-85.1	NA
300,000 to 599,999 tpy:						
Mean	[1] 84.6	64.3	NA	66.2	[1] 79.8	74.0
Standard deviation	5.2	15.3	NA	7.9	3.3	6.9
Number of sections	29	16	NA	12	17	11
Range of sample	66.5-91.7	33.0-87.3	NA	45.8-77.2	75.0-85.9	66.2-82.0
600,000 to 899,999 tpy:						
Mean	80.2	62.8	NA	[1] 70.4	77.9	[2] 66.4
Standard deviation	6.2	10.8	NA	2.6	5.9	2.4
Number of sections	29	16	NA	6	14	7
Range of sample	70.0-89.7	48.0-81.3	NA	67.5-73.9	69.3-93.9	63.0-69.8
>900,000 tpy:						
Mean	[2] 73.2	[2] 56.3	NA	[2] 56.8	[2] 74.5	68.7
Standard deviation	8.7	8.3	NA	4.4	3.3	NA
Number of sections	13	6	NA	5	10	1
Range of sample	61.3-91.9	42.8-66.6	NA	50.0-62.3	66.9-78.9	NA

NA Not available.

[1] Group mean is significantly higher than the mean for all sections using the indicated mining system.

[2] Group mean is significantly lower than the mean for all sections using the indicated mining system.

TABLE 6. - Group statistics using recovery figures excluding all barrier areas within a section, by the market indicated as served and mining method

Market served and parameter	Mining method					
	Continuous		Conventional		Longwall	Shortwall
	Full pillar	Partial pillar	Full pillar	Partial pillar		
Steam:[1]						
Mean	79.7	63.0	NA	65.4	77.7	[2]67.4
Standard deviation	8.0	13.5	NA	11.0	5.3	2.7
Number of sections	38	51	NA	31	14	14
Range of sample	61.3-91.9	33.0-87.7	NA	38.4-87.1	69.3-85.9	63.0-73.8
Metallurgical:[1]						
Mean	[3]82.4	[3]70.4	75.6	70.2	79.0	[3]80.8
Standard deviation	6.1	8.7	2.3	10.3	4.6	.9
Number of sections	52	22	3	17	36	5
Range of sample	66.5-91.9	48.2-83.0	73.0-77.6	45.8-87.1	66.9-93.9	79.6-82.0
Steam:						
Mean	[2]77.2	60.9	NA	62.6	[2]75.3	[2]67.4
Standard deviation	8.2	13.6	NA	10.3	4.3	2.7
Number of sections	26	39	NA	19	9	14
Range of sample	61.3-91.9	33.0-87.7	NA	38.4-73.9	69.3-80.6	63.0-73.8
Steam and metallurgical:						
Mean	[3]85.1	69.8	NA	69.9	81.9	NA
Standard deviation	3.9	10.7	NA	11.1	4.3	NA
Number of sections	12	12	NA	12	5	NA
Range of sample	78.2-91.9	48.2-83.0	NA	60.0-87.1	75.4-85.9	NA
Metallurgical:						
Mean	81.5	[3]71.2	75.6	71.1	78.6	[3]80.8
Standard deviation	6.4	5.8	2.3	8.9	4.6	.9
Number of sections	40	10	3	5	31	5
Range of samples	66.5-91.7	62.3-81.3	73.0-77.6	60.1-80.6	66.9-93.9	79.6-82.0

NA Not available.

[1] Includes sections from mines which supply both steam and metallurgical markets.

[2] Group mean is significantly lower than the mean for all sections using the indicated mining system.

[3] Group mean is significantly higher than the mean for all sections using the indicated mining system

TABLE 7. - Group statistics using recovery figures excluding all barrier areas within a section, by the market indicated as served, thickness category, and mining method

Thickness category and parameter	Mining method					
	Continuous		Conventional		Longwall	Shortwall
	Full pillar	Partial pillar	Full pillar	Partial pillar		
STEAM MARKET[1]						
<40 inches:						
Mean	NA	70.7	NA	NA	NA	NA
Standard deviation	NA	4.0	NA	NA	NA	NA
Number of sections	NA	2	NA	NA	NA	NA
Range of sample	NA	67.9-73.5	NA	NA	NA	NA
40 to 59 inches:						
Mean	82.7	[2]69.3	NA	66.9	[2]81.3	65.7
Standard deviation	4.7	10.3	NA	7.7	3.4	NA
Number of sections	16	23	NA	21	8	1
Range of sample	73.3-88.3	52.2-87.7	NA	45.8-77.2	75.4-85.9	NA
60 to 79 inches:						
Mean	83.1	58.8	NA	68.0	NA	[3]68.3
Standard deviation	5.8	12.9	NA	12.0	NA	3.0
Number of sections	12	13	NA	8	NA	6
Range of sample	74.0-91.9	42.8-87.3	NA	56.8-87.1	NA	66.2-73.8
80 to 99 inches:						
Mean	[3]69.2	52.0	NA	38.4	[3]72.8	[3]66.9
Standard deviation	4.9	15.6	NA	NA	2.6	2.5
Number of sections	6	5	NA	1	6	7
Range of sample	61.9-73.7	33.0-69.5	NA	NA	69.3-75.4	63.0-69.8
>99 inches:						
Mean	73.5	56.4	NA	40.2	NA	NA
Standard deviation	12.4	14.7	NA	NA	NA	NA
Number of sections	4	8	NA	1	NA	NA
Range of sample	61.3-88.2	36.8-81.3	NA	NA	NA	NA

METALLURGICAL MARKET[1]						
<40 inches:						
Mean	76.0	68.7	75.6	NA	NA	NA
Standard deviation	5.3	6.2	2.3	NA	NA	NA
Number of sections	2	2	3	NA	NA	NA
Range of sample	72.2-79.7	64.3-73.1	73.0-77.6	NA	NA	NA
40 to 59 inches:						
Mean	82.0	[2]72.0	NA	68.2	79.6	[2]81.6
Standard deviation	6.0	8.4	NA	9.0	3.7	.6
Number of sections	25	12	NA	15	19	2
Range of sample	66.5-89.7	59.2-83.0	NA	45.8-80.6	74.0-85.9	81.1-82.0
60 to 79 inches:						
Mean	[2]83.0	77.0	NA	[2]85.6	77.4	[2]80.3
Standard deviation	6.0	4.7	NA	2.2	3.8	.7
Number of sections	23	2	NA	2	16	3
Range of sample	70.6-91.7	73.7-80.3	NA	84.0-87.1	66.9-81.8	79.6-80.2
80 to 99 inches:						
Mean	85.9	65.6	NA	NA	93.9	NA
Standard deviation	8.1	9.7	NA	NA	NA	NA
Number of sections	2	6	NA	NA	1	NA
Range of sample	80.2-91.6	48.2-75.0	NA	NA	NA	NA
>99 inches:						
Mean	NA	NA	NA	NA	NA	NA
Standard deviation	NA	NA	NA	NA	NA	NA
Number of sections	NA	NA	NA	NA	NA	NA
Range of sample	NA	NA	NA	NA	NA	NA

NA Not available.

[1] Includes sections from mines which supply both steam and metallurgical markets.

[2] Group mean is significantly higher than the mean for all sections using the indicated mining system.

[3] Group mean is significantly lower than the mean for all sections using the indicated mining system.

TABLE 8. - Group statistics using recovery figures excluding all barrier areas within a section, by the market indicated as served, the mine's 1976 level of production, and mining method

Production in 1976 and parameter	Mining method					
	Continuous		Conventional		Longwall	Shortwall
	Full pillar	Partial pillar	Full pillar	Partial pillar		
STEAM MARKET[1]						
<300,000 tpy:						
Mean	NA	68.1	NA	69.3	NA	NA
Standard deviation	NA	15.9	NA	13.7	NA	NA
Number of sections	NA	13	NA	9	NA	NA
Range of sample	NA	36.8-87.7	NA	40.2-87.1	NA	NA
300,000 to 599,999 tpy:						
Mean	[2]84.6	64.3	NA	65.9	[2]81.4	[3]68.3
Standard deviation	4.1	15.3	NA	8.5	3.7	3.0
Number of sections	13	16	NA	10	7	6
Range of sample	78.2-91.4	33.0-87.3	NA	45.8-77.2	75.4-85.9	66.2-73.8
600,000 to 899,999 tpy:						
Mean	80.5	60.1	NA	[2]70.4	73.3	[3]66.4
Standard deviation	6.0	9.7	NA	2.6	6.3	2.4
Number of sections	14	13	NA	6	3	7
Range of sample	70.0-88.2	48.0-76.8	NA	67.5-73.9	69.3-80.6	63.0-69.8
>900,000 tpy:						
Mean	[3]72.9	[3]56.3	NA	[3]56.8	[3]74.3	68.7
Standard deviation	9.3	8.3	NA	4.4	1.2	NA
Number of sections	11	6	NA	5	4	1
Range of sample	61.3-91.9	42.8-66.6	NA	50.0-62.3	73.1-75.4	NA

	METALLURGICAL MARKET[1]					
<300,000 tpy:						
Mean	79.8	[2]70.8	75.6	[2]75.8	81.0	NA
Standard deviation	4.3	9.3	2.3	9.1	3.9	NA
Number of sections	7	13	3	8	5	NA
Range of sample	72.2-85.7	48.2-83.0	73.0-77.6	60.1-87.1	74.6-85.1	NA
300,000 to 599,999 tpy:						
Mean	[2]84.8	67.1	NA	65.3	79.8	[2]80.8
Standard deviation	5.2	7.4	NA	9.0	3.5	.9
Number of sections	28	7	NA	9	15	5
Range of sample	66.5-91.7	59.2-78.8	NA	45.8-77.2	75.0-85.9	79.6-82.0
600,000 to 899,999 tpy:						
Mean	80.0	77.6	NA	NA	79.6	NA
Standard deviation	6.5	5.2	NA	NA	5.5	NA
Number of sections	15	2	NA	NA	10	NA
Range of sample	70.7-89.7	73.9-81.3	NA	NA	74.0-93.9	NA
>900,000 tpy:						
Mean	74.5	NA	NA	NA	74.7	NA
Standard deviation	5.5	NA	NA	NA	4.4	NA
Number of sections	2	NA	NA	NA	6	NA
Range of sample	70.6-78.4	NA	NA	NA	66.9-78.9	NA

NA Not available.

[1] Includes sections from mines which supply both steam and metallurgical markets.

[2] Group mean is significantly higher than the mean for all sections using the indicated mining system.

[3] Group mean is significantly lower than the mean for all sections using the indicated mining system.

TABLE 9. - Group statistics using recovery figures excluding all barrier areas within a section, by the mine's 1976 level of production, thickness category, and mining method

Thickness category and parameter	Mining method					
	Continuous		Conventional		Longwall	Shortwall
	Full pillar	Partial pillar	Full pillar	Partial pillar		
<300,000-TPY PRODUCTION IN 1976						
<40 inches:						
Mean..................	76.0	[1]69.7	75.6	NA	NA	NA
Standard deviation....	5.3	4.4	2.3	NA	NA	NA
Number of sections....	2	4	3	NA	NA	NA
Range of sample.......	72.2-79.7	64.3-73.5	73.0-76.1	NA	NA	NA
40 to 59 inches:						
Mean..................	82.4	[1]78.4	NA	70.2	[1]82.6	NA
Standard deviation....	2.7	6.6	NA	7.3	1.7	NA
Number of sections....	4	6	NA	9	4	NA
Range of sample.......	79.0-85.7	68.6-87.7	NA	60.1-80.6	81.3-85.1	NA
60 to 79 inches:						
Mean..................	77.5	80.3	NA	[1]85.6	74.6	NA
Standard deviation....	NA	NA	NA	2.2	NA	NA
Number of sections....	1	1	NA	2	1	NA
Range of sample.......	NA	NA	NA	84.0-87.1	NA	NA
80 to 99 inches:						
Mean..................	NA	62.4	NA	NA	NA	NA
Standard deviation....	NA	12.3	NA	NA	NA	NA
Number of sections....	NA	7	NA	NA	NA	NA
Range of sample.......	NA	43.0-75.0	NA	NA	NA	NA
>99 inches:						
Mean..................	NA	50.9	NA	40.2	NA	NA
Standard deviation....	NA	19.9	NA	NA	NA	NA
Number of sections....	NA	2	NA	1	NA	NA
Range of sample.......	NA	36.8-65.0	NA	NA	NA	NA

	300,000- TO 599,999-TPY PRODUCTION IN 1976					
<40 inches:						
Mean..................	NA	NA	NA	NA	NA	NA
Standard deviation....	NA	NA	NA	NA	NA	NA
Number of sections....	NA	NA	NA	NA	NA	NA
Range of sample.......	NA	NA	NA	NA	NA	NA
40 to 59 inches:						
Mean..................	[1]83.6	69.5	NA	66.2	80.2	[1]81.6
Standard deviation....	5.6	9.6	NA	7.9	3.8	.6
Number of sections....	15	8	NA	12	11	2
Range of sample.......	66.5-88.3	59.2-86.4	NA	45.8-77.2	75.0-85.9	81.1-82.0
60 to 79 inches:						
Mean..................	[1]85.8	62.2	NA	NA	79.1	72.3
Standard deviation....	4.4	17.3	NA	NA	2.1	6.4
Number of sections....	12	4	NA	NA	6	9
Range of sample.......	78.2-91.7	48.1-87.3	NA	NA	76.7-81.8	66.2-81.0
80 to 99 inches:						
Mean..................	91.6	33.0	NA	NA	NA	NA
Standard deviation....	NA	NA	NA	NA	NA	NA
Number of sections....	1	1	NA	NA	NA	NA
Range of sample.......	NA	NA	NA	NA	NA	NA
>99 inches:						
Mean..................	79.0	63.6	NA	NA	NA	NA
Standard deviation....	NA	19.0	NA	NA	NA	NA
Number of sections....	1	3	NA	NA	NA	NA
Range of sample.......	NA	43.5-81.3	NA	NA	NA	NA

See footnotes at end of table.

TABLE 9. - Group statistics using recovery figures excluding all barrier areas within a section, by the mine's 1976 level of production, thickness category, and mining method--Continued

Thickness category and parameter	Mining method					
	Continuous		Conventional		Longwall	Shortwall
	Full pillar	Partial pillar	Full pillar	Partial pillar		
600,000- TO 899,999-TPY PRODUCTION IN 1976						
<40 inches:						
Mean..................	NA	NA	NA	NA	NA	NA
Standard deviation....	NA	NA	NA	NA	NA	NA
Number of sections....	NA	NA	NA	NA	NA	NA
Range of sample.......	NA	NA	NA	NA	NA	NA
40 to 59 inches:						
Mean..................	79.1	65.7	NA	[1]70.8	77.3	65.7
Standard deviation....	6	10.0	NA	2.8	2.0	NA
Number of sections....	11	11	NA	4	7	1
Range of sample.......	71.5-89.7	52.2-81.3	NA	67.9-73.9	74.0-80.6	NA
60 to 79 inches:						
Mean..................	81.7	[2]49.0	NA	69.5	80.5	NA
Standard deviation....	5.6	1.3	NA	2.8	1.5	NA
Number of sections....	14	2	NA	2	3	NA
Range of sample.......	70.7-88.5	48.0-49.9	NA	67.5-71.4	78.8-81.6	NA
80 to 99 inches:						
Mean..................	74.6	68.0	NA	NA	77.8	[2]66.6
Standard deviation....	5.2	2.2	NA	NA	14.0	2.6
Number of sections....	3	2	NA	NA	3	6
Range of sample.......	70.0-80.2	66.4-69.5	NA	NA	69.3-93.9	63.0-69.8
>99 inches:						
Mean..................	88.2	48.9	NA	NA	NA	NA
Standard deviation....	NA	NA	NA	NA	NA	NA
Number of sections....	1	1	NA	NA	NA	NA
Range of sample.......	NA	NA	NA	NA	NA	NA

	>900,000-TPY PRODUCTION IN 1976					
<40 inches:						
Mean..................	NA	NA	NA	NA	NA	NA
Standard deviation....	NA	NA	NA	NA	NA	NA
Number of sections....	NA	NA	NA	NA	NA	NA
Range of sample.......	NA	NA	NA	NA	NA	NA
40 to 59 inches:						
Mean..................	81.0	NA	NA	50.0	NA	NA
Standard deviation....	7.9	NA	NA	NA	NA	NA
Number of secions.....	4	NA	NA	1	NA	NA
Range of sample.......	73.3-91.9	NA	NA	NA	NA	NA
60 to 79 inches:						
Mean..................	76.3	[1]56.3	NA	[2]58.5	74.7	NA
Standard deviation....	5.0	8.3	NA	2.6	4.4	NA
Number of sections....	3	6	NA	4	6	NA
Range of sample.......	70.6-79.8	42.8-66.6	NA	56.8-62.3	66.9-78.9	NA
80 to 99 inches:						
Mean..................	[2]67.9	NA	NA	NA	[2]74.3	68.7
Standard deviation....	5.5	NA	NA	NA	1.2	NA
Number of sections....	4	NA	NA	NA	4	1
Range of sample.......	61.9-73.7	NA	NA	NA	73.1-75.4	NA
>99 inches:						
Mean..................	[2]63.4	NA	NA	NA	NA	NA
Standard deviation....	3.0	NA	NA	NA	NA	NA
Number of sections....	2	NA	NA	NA	NA	NA
Range of sample.......	61.3-65.5	NA	NA	NA	NA	NA

NA Not available.

[1] Group mean is significantly higher than the mean for all sections using the indicated mining system.

[2] Group mean is significantly lower than the mean for all sections using the indicated mining system.

TABLE 10. - Unquantifiable factors identified by mine personnel as adversely affecting recovery

Factors adversely affecting recovery	Frequency mentioned
Bad roof conditions	32
Water problems	29
Faults, wants, washouts	25
Oil and gas wells on mine property	12
Clay veins	8
Rolls in the coalbed	8
Bad floor conditions	7
Coalbed splitting	6
Coalbed squeezing	6
Displacement faults	4
Excessive coalbed dip	4
Excessive depth of cover	4
Property line barriers	4
Subsidence constraints	4
Shallow depth of cover	4
Areas of thin coal in the mine	3
Outcrop barriers	3
Variable coalbed thickness	3
Sloughing of rib coal	3
Haulage spillage	2
State and Federal laws	2
Stratigraphic closeness of two coalbeds	2
Equipment maintenance	1
Methane	1

TABLE 11. - Composite statistics of mine personnel estimates of recovery including barrier areas, by mining method

Mining method	Mean	Standard deviation	Number of sections	Range of sample
Continuous:				
Full pillar	73.1	10.8	77	50.0- 95.0
Partial pillar	61.3	12.0	57	33.0- 85.0
Conventional:				
Full pillar	NA	NA	NA	NA
Partial pillar	59.7	7.8	33	45.0- 75.0
Longwall	74.4	9.0	39	58.0- 90.0
Shortwall	84.3	7.1	15	72.0-100.0

NA Not available.

CONCLUSIONS

The following conclusions seem justified based on the statistical tests performed on the quantifiable data and on an objective look at the unquantifiable data:

1. Regarding recovery percentages by mining method, the order from highest to lowest using estimates that include barrier areas is (1) longwall mining, (2) continuous mining with full pillar extraction, (3) shortwall mining, (4) conventional mining with full pillar extraction, (5) conventional mining with partial pillar extraction, and (6) continuous mining with partial pillar extraction. Using estimates that exclude barrier areas, the order changes to (1) continuous mining with full pillar extraction, (2) longwall mining, (3) conventional mining with full pillar extraction, (4) shortwall mining, (5) conventional mining with partial pillar extraction, and (6) continuous mining with partial pillar extraction. The change in order of the first four mining methods in these two rankings is probably a reflection of conditions necessary for successful employment of longwall and shortwall mining systems, such as large blocks of undisturbed coal of uniform thickness (tables 2 and 3).

2. Using recovery estimates with and without barriers, no State appears to hold a significant advantage or disadvantage in relation to other major coal-producing States (tables 2 and 2).

3. Recovery seems better for those sections mined in less than 80 inches of coal, even though significant improvement is shown only for continuous mining with full pillar extraction (60 to 79 inches), continuous mining with partial pillar extraction (40 inches, 40 to 59 inches), and longwall mining (40 to 59 inches) (table 4).

4. Recovery is significantly lower in mines producing more than 900,000 tpy for continuous mining with full and partial pillar extraction, conventional mining with partial pillar extraction, and longwall mining (table 5).

5. Recovery seems lower for those sections in which the coal was produced strictly for steam coal markets (table 6).

6. There seems to be lower recovery of coal for steam markets from beds greater than 80 inches thick. Significant differences are found for continuous mining with full pillar extraction (80 to 99 inches), longwall mining (80 to 99 inches), and shortwall mining (80 to 99 inches) (table 7).

7. Recovery of steam coal from mines producing more than 600,000 tpy is lower in eight of nine categories for which data are available (table 8). In five categories it is significantly lower.

8. Mines producing less than 600,000 tpy from coalbeds less than 80 inches thick seem to have better recovery than larger or similar size mines in thicker coalbeds (table 9).

9. Regarding possible studies of the unquantifiable factors identified in this report, their effect on recovery is possibly related to their frequency of citation (table 10).

10. Estimates of recovery made using the procedure developed in this report bracket the estimates made by mine personnel (table 11).

While this study does present composite estimates of recovery using different mining systems, it is not recommended that these figures be used as the final word for estimating recovery. The procedure used to determine these figures represents only one method of arriving at an estimate. Therefore these figures may not be applicable to all situations.

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